Advanced Modeling & Simulation in PRA

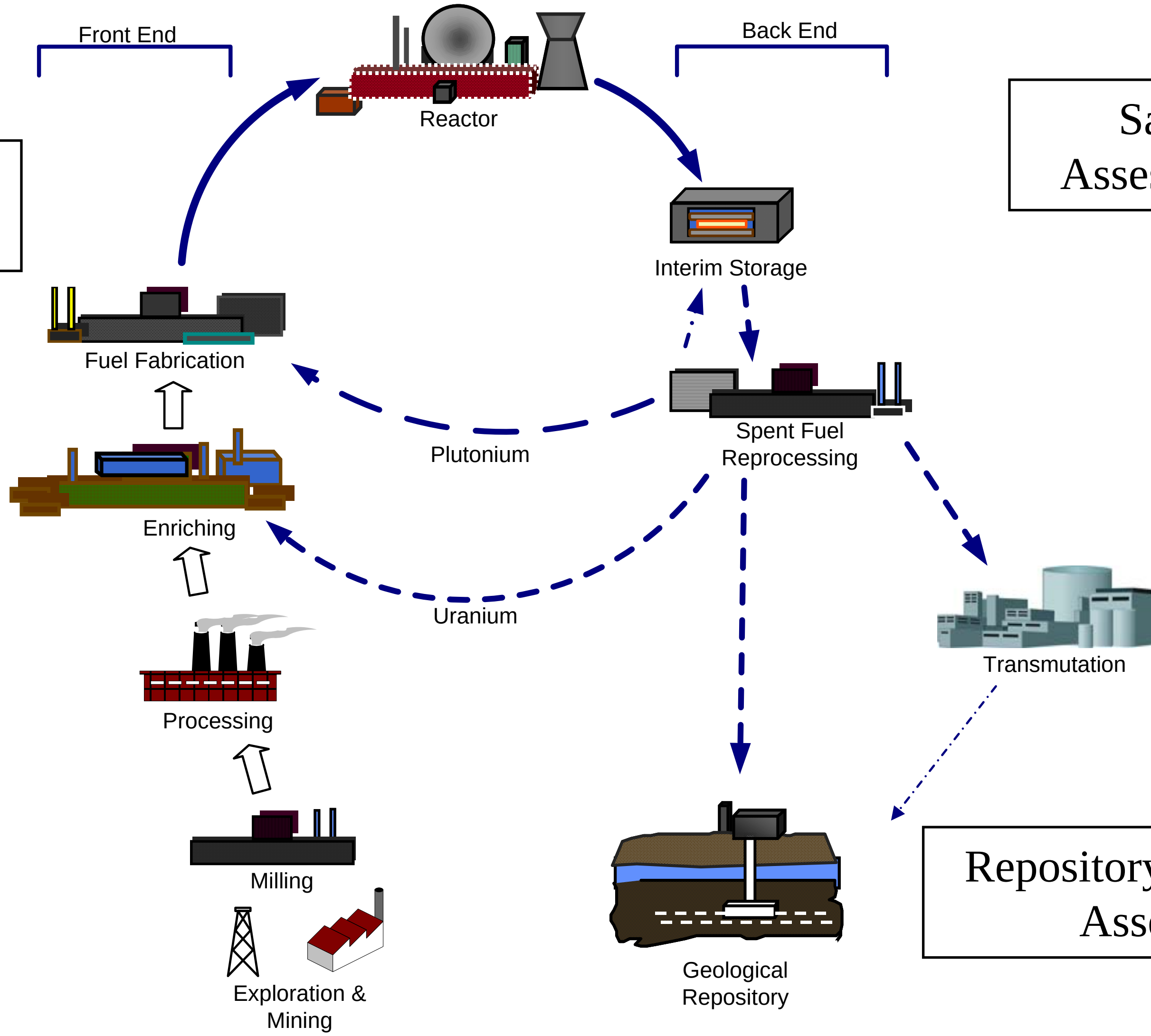
Advanced Simulations Workshop

December 15, 2005

John E Kelly
Advanced Nuclear Energy Programs
Sandia National Laboratories

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

There are PRA Applications in the Nuclear Fuel Cycle



Security Assessments

Safety Assessments

Repository Performance Assessment

Sandia National Laboratories

Historical Perspective

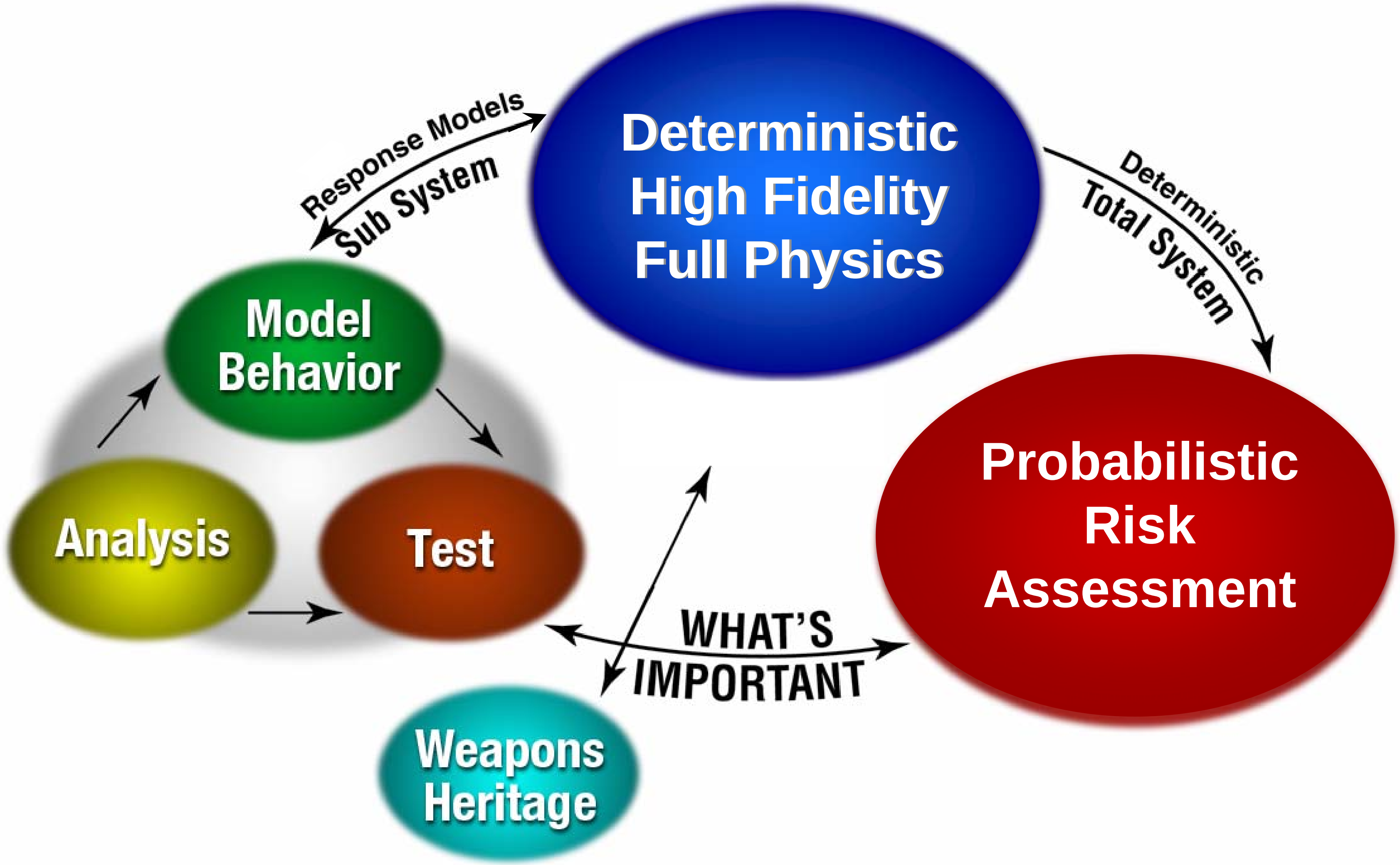
- Until recently, PRAs relied on expert judgment or simplified analyses (sometimes bounding) for quantifying the consequences of accident scenarios
- This process introduced uncertainty and created significant debate about the relative importance of complex phenomena (confidence)
- A key issue was, with limited testing (i.e. physical simulation), different models could explain the data, but in the PRA application these would produce significantly different results
- At the same time, the limitations in computing power severally restricted the numerical simulations that could be performed
- In some sense, the complexity of the PRA process and its results overwhelmed the need for a more detailed understanding of phenomena

Today's Outlook

- Advanced Modeling and Simulation is just beginning to be integrated into risk assessments
- ASCI-level simulations have been used in some PRA studies
  - Post 9/11 Security Assessments
  - Nuclear Launch Safety
- Roles of High-Fidelity, Coupled-Physics Simulations
  - Extending test data to a range of scenarios
  - Filling in information gaps where experiments cannot be performed
  - Quantifying accident progression and consequences

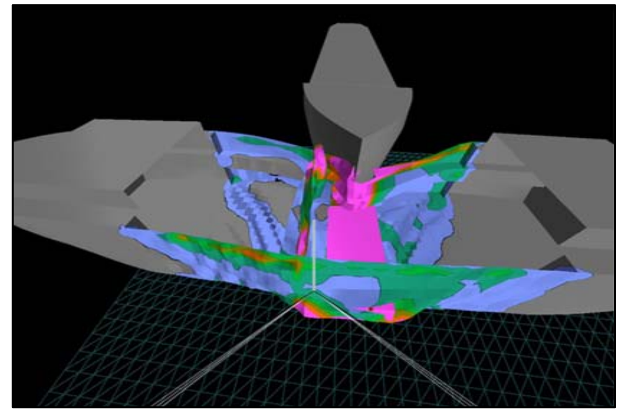
Sandia National Laboratories

INTEGRATED SYSTEMS ANALYSIS APPROACH

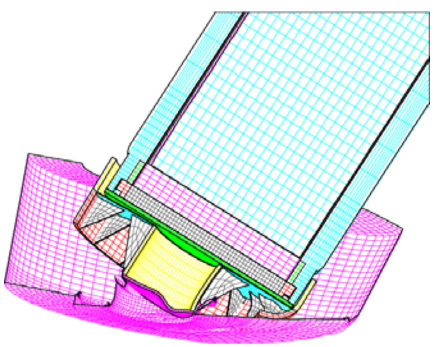


Advanced Modeling and Simulation in Transportation Risk Assessment

Certification tests

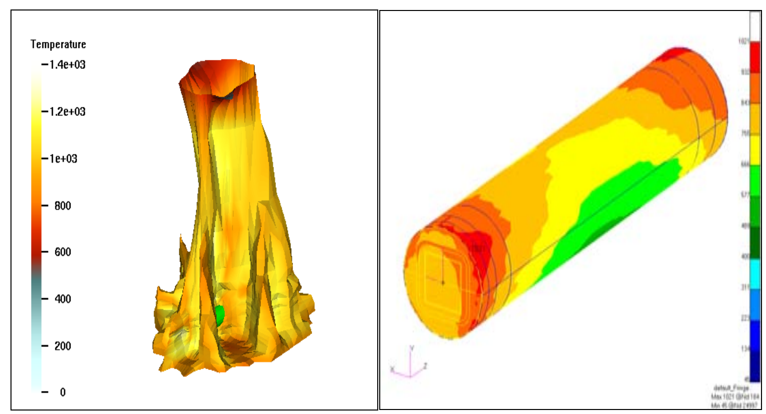


Ship collision analysis



Structural analyses

Web-based risk communication

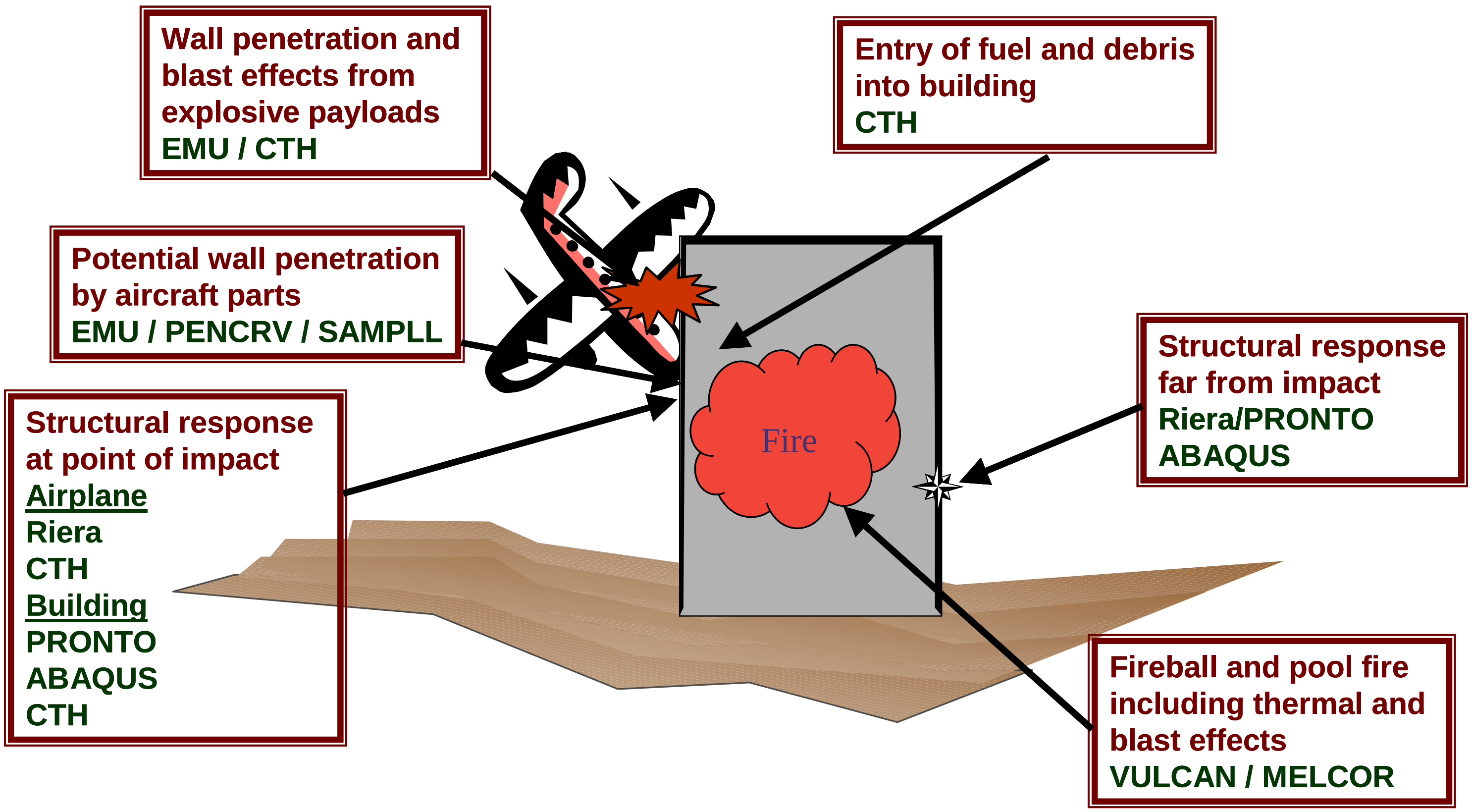


Thermal analysis

Sandia National Laboratories

UNCLASSIFIED

Structural and Fire Analysis Tools (U)



UNCLASSIFIED

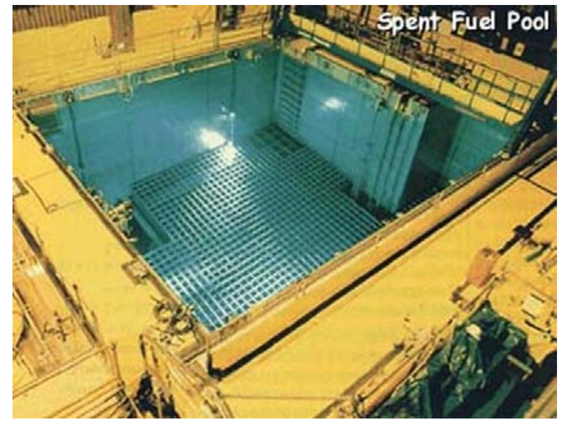
Today's Challenges

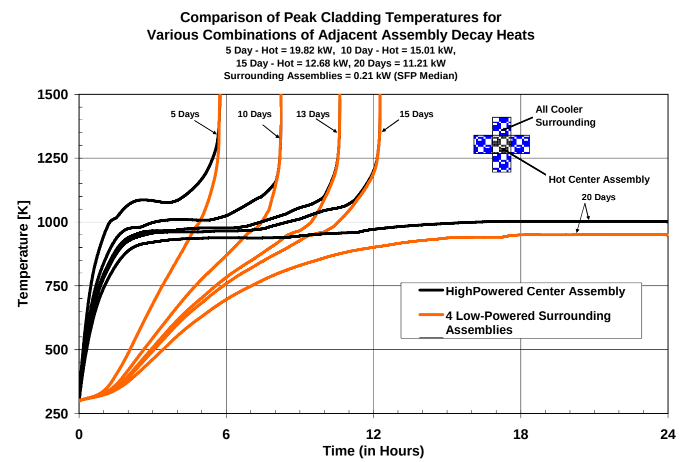
- Many of the safety and security questions being considered in risk assessments today are beyond the state-of-the-art in Modeling & Simulation

- We will need more testing and better simulation tools to fully understand accident progression

High-Performance Computing in Nuclear Security: Example of NAS Spent Fuel Pool Study

- **Planned state-of-art assessments for fuel pool “accidents” will use**
  - **Integrate source term modeling capability (MELCOR)**
  - **CFD tools for modeling gross circulation patterns in building**
- **NAS review panel identified need for high-fidelity process models within an integrated accident code (such capability does not currently exist)**



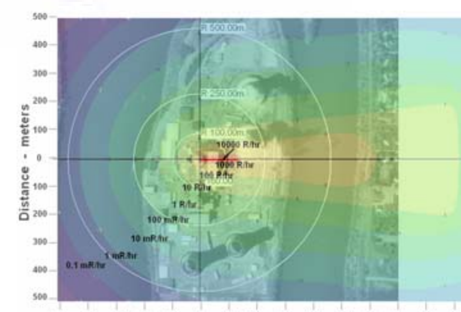


Sandia National Laboratories

Evaluating Accident Response
High-Performance Computing Needs

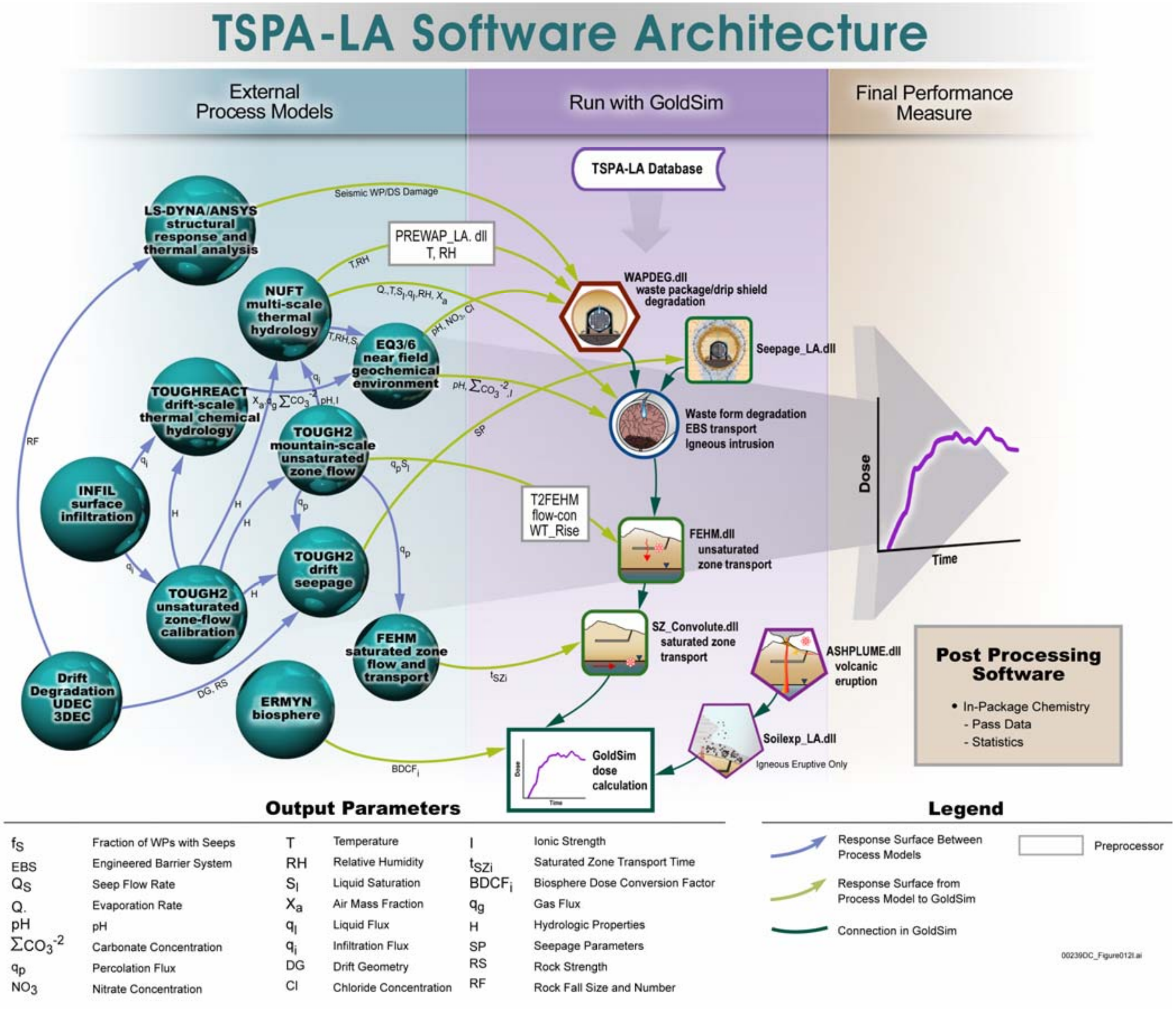
Sprays or foams may be effective for keeping large radioactive releases on-site. Incorporation of spatial dependence and integration of phenomena on multiple scales are key needs for high-fidelity modeling in these areas:

- **Agglomeration behavior of fission product aerosols in the presence of smoke or other particulates**
- **Spray droplet behavior**
- **Trapping and/or stabilization of fission products using foams**
- **Stabilization of aqueous iodine using water sprays**
- **Atmospheric transport for detailed dose mapping**
- **Behavior and interactions of fires**



Sandia National Laboratories

Modeling and Simulation in Repository Performance Assessment



Sandia National Laboratories

Modeling and Simulation to Support Future Nuclear Fuel Cycle PRAs

Fast Reactors

We will need to demonstrate passive safety and margin to melt (unprotected LOF)
With limited testing, M&S will play a vital role
This implies high-fidelity, coupled neutronic, thermal, fluid, and structural analysis

Spent Fuel Treatment Facility

Both safety and security PRAs will be needed.
Likely that high-fidelity M&S will be needed to address licensing questions and support PRA

Some Concluding Remarks

NNSA's ASC Program has achieved much, but it also imparted a *"dose of reality"*

- **M&S is important and valuable, but it can't do it all**
  - **Take care not to over promise**
- **It is attractive to develop a *modular toolkit* of software capabilities that support *multi-resolution* simulations of the complex multi-scale and multi-physics phenomena of interest**
  - **Supports earlier availability; incremental enhancements; and flexibility**
  - **Supports graded analysis, adaptivity, and agility**
- **Need to pay attention to the whole simulation job**
  - **Problem Solving Environment**
    - **Meshing, Scalable Codes, Algorithms, Visualization**

Sandia National Laboratories